Q GENERATORS Q ELECTRONS Q POWER STATIONS

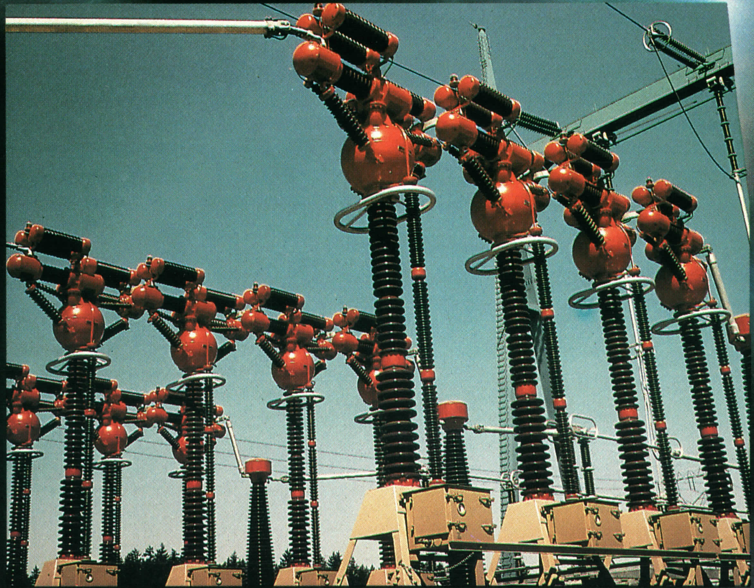
ELECTRICITY

Phil Jude/Science Photo Library

A discharge of electricity flashes from one metal object to another. Metal has the kind of molecular structure that makes it an ideal conductor, so that it naturally attracts any unchannelled electricity.

WITH THE FLICK OF A SWITCH, a light, a stereo, a microwave oven or a computer comes instantly to life. These devices, and thousands of others that we take for granted in the modern world, work off electricity. But what is electricity and where does it come from?

An electrical current is a flow of tiny particles called electrons. Electrons are one of the basic building blocks of atoms, and are negatively charged: this means that they repel each other. Normally, the electrons swarm in clouds around the atom's nucleus, or centre, made up of a cluster of positively charged protons and neutrons. In some atoms, however,



US Dept of Energy/SPL

***Circuit breakers**, like these ones at an electricity substation at Oregon City, USA, are a safety device. If lightning strikes an overhead cable, the circuit breakers switch off power to the rest of the cable to protect it.*

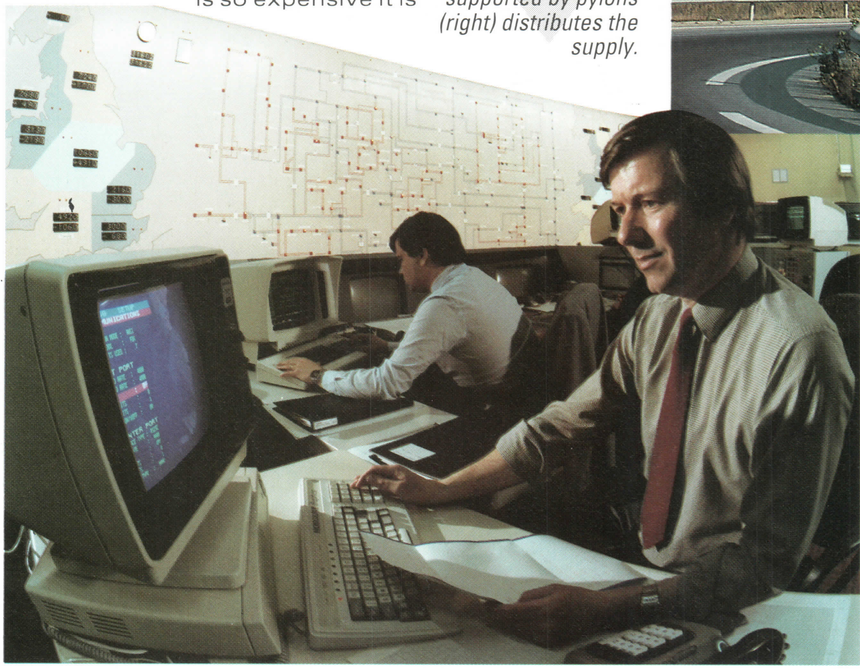
some of the electrons are 'free' and orbit outside the atom. These free-electrons can travel in streams from one place to another, creating a current of electricity.

Substances such as metals, which contain many free or loosely held electrons, are known as conductors, since they allow electricity to pass through them very easily. Silver is one of the best conductors, but because it is so expensive it is used only for the most crucial connections in devices such as computers. The best low-cost conductor, used for virtually all wiring, is copper.

Most other materials, including plastics, ceramics, rubber, wood and paper, have very few free electrons and so prevent electricity from flowing through them. They are called insulators. Household wiring, for instance, consists of a bundle of current-carrying copper wire, surrounded by an insulating layer of plastic to prevent the current from escaping. Devices that produce high temperatures, such as electric oven rings and car engines, need better insulation, so ceramic insulators are used instead of plastics.

The path an electric current takes as it flows is called a circuit. In a torch, for example – one of the simplest possible circuits – a battery provides a supply of electrons, which flow through a wire to a bulb and then back again to the battery. Although the wire is a good conductor, some electrons do collide with the atoms in the wire, which slows them down. This slowing down effect is known as resistance.

Berenguier/Jerrican



National Grid Co

The control room *of a national grid system is the nerve centre of a country's electricity supply. Here, supply can be monitored, and then redirected to where it is most needed. A network of cables supported by pylons (right) distributes the supply.*

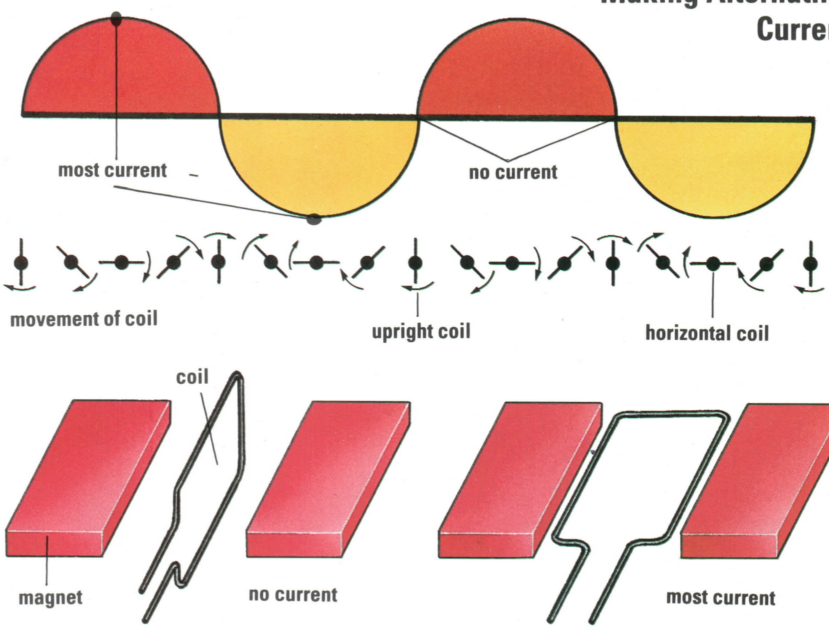
Glowing filament

Inside the light bulb, a very thin wire or filament offers much more resistance to the electrons as they squeeze through it. But so many collisions occur in the filament that it quickly becomes hot and begins to glow.

A battery supplies one-way, or direct current (DC). But mains electricity is constantly changing direction and is known as alternating current (AC). The frequency of change varies from one country to another but is in the range 50 to 60 times per second.

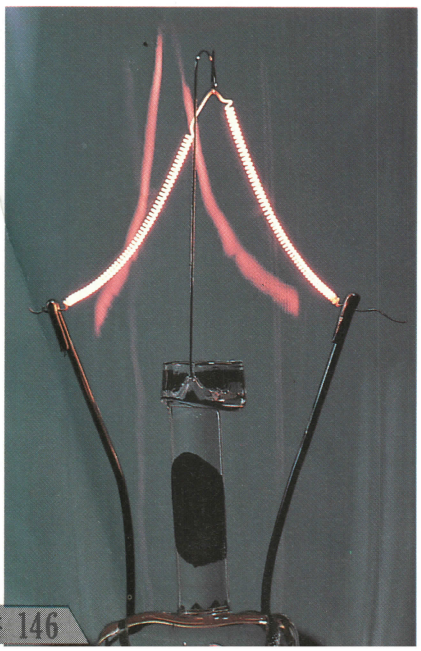
Mains electricity is made in power stations. It is then sent through a

Making Alternating Current



Mark Franklin

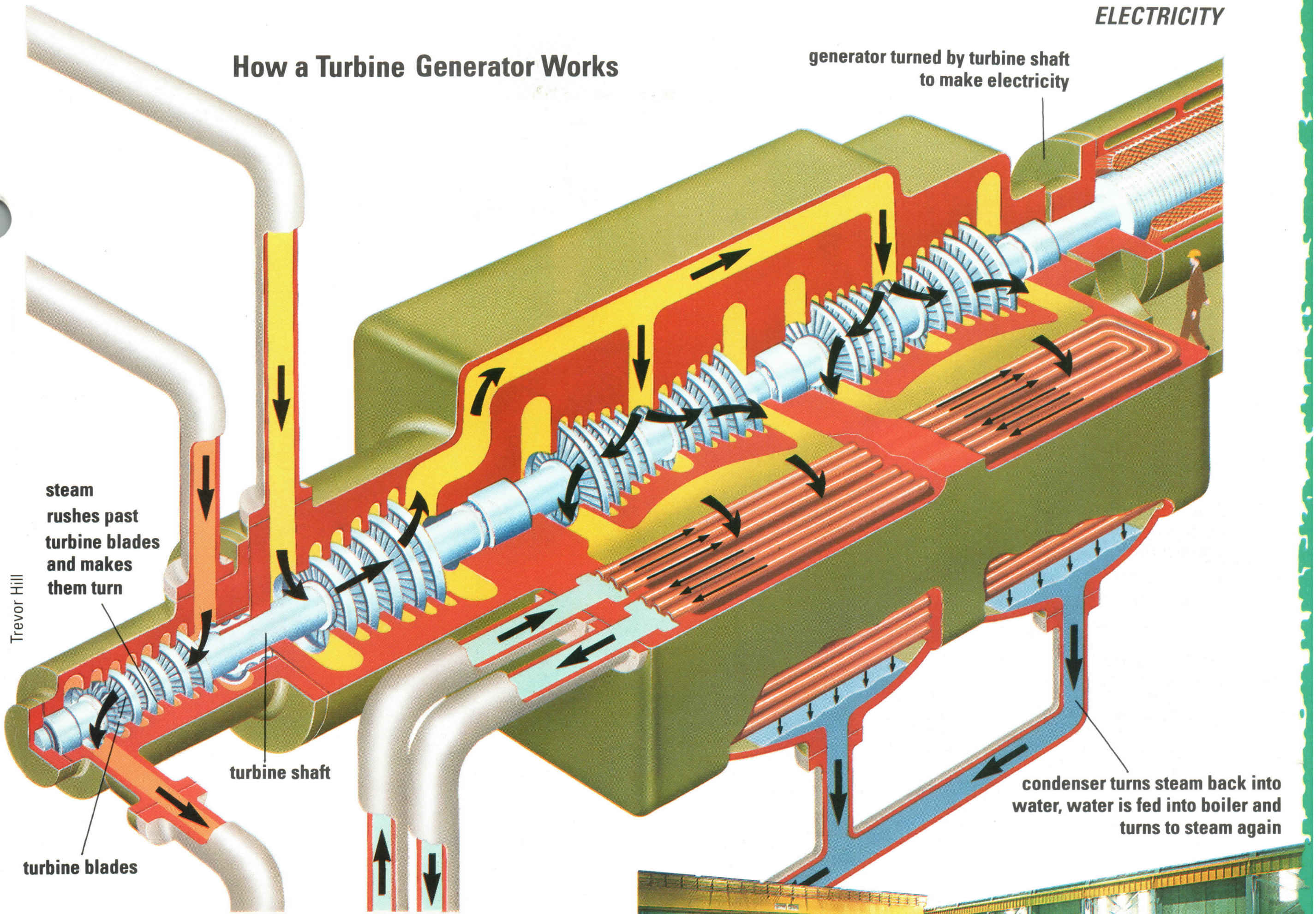
Electricity *can be generated by rotating a coil in a magnetic field. This produces a current that varies (top) according to the position of the coil.*



Ray Ellis/Science Photo Library

The filament in a light bulb *is made of very fine wire. Electrons keep bumping into the atoms in the wire, making them vibrate and glow white with heat.*

How a Turbine Generator Works



network of cables known as a national grid to all parts of the country.

In the power station, heat from burning coal or oil, or from a nuclear reactor, is used to convert water into steam for turning the blades of a huge turbine. A shaft from the turbine is connected to a generator in which magnets are made to spin rapidly inside a large copper coil. The rotation of the magnets produces a huge amount of current in the coil.

The force with which electrical current is driven through cables is measured in volts. The higher the voltage, the less electricity is 'lost' through resistance and heating of the cable. So, before electricity leaves the power station, the voltage is stepped up from between 10,000 and 30,000 volts to between 100,000 and 400,000 volts.

This is easily done with the help of a transformer consisting of two coils of wire wrapped around opposite sides of an iron core. If the number of turns in the outgoing, or secondary, coil is greater than the number of turns in the incoming, or primary, coil then the voltage will be increased. If the situation is reversed, the voltage is similarly decreased.

HIGH-SPEED POWER

The flow of electricity through a wire can be likened to the movement of water down a pipe. The rate at which water passes through the pipe depends on the pipe's width and on the difference in water pressure between the two ends of the pipe.

In the same way, the amount of current flowing through a circuit depends on the resistance of the circuit – which is measured in ohms – and the voltage – which is measured in volts. A 9-volt battery, for example, will produce six times more current through a given circuit than a 1.5-volt battery.

Current is measured in ampères, or amps. One ampère represents a flow of about 6.3 million trillion individual electrons per second.

Steam forcing its way past the angled turbine blades turns the shaft. This turns an electromagnet inside a coil, which makes electricity in the same way as turning a coil in a magnetic field. The steam comes from burning coal or oil or (right) a nuclear reactor.

Alex Bartel/SPL

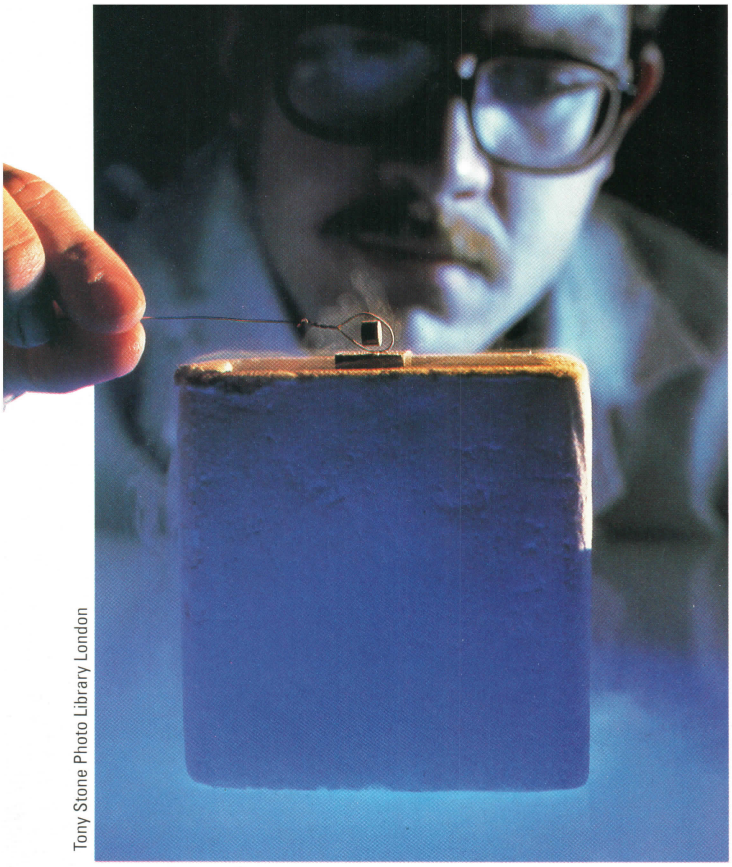
Step-down

Upon reaching the outskirts of a town or city, the power lines enter a substation where the voltage is decreased by a step-down transformer until it is again between 10,000 and 30,000 volts. This reduces the danger if power lines come down in heavily-populated areas.

Before electricity is allowed to enter people's homes, the voltage is once more reduced by a transformer in a smaller substation. The final domestic supply ranges between 110 volts in the United States to 230 volts in Britain. Large factories often have their own transformers because they need a higher voltage supply.

Switching power

By linking power stations and transmission lines together through a national grid, power can be switched from one area of a country to another as demand changes. But even this is sometimes not enough. When, in 1990, the estimated 30 million British television viewers of the England–West Germany World Cup semi-final turned on their electric kettles at half-time, the extra power drain was



Tony Stone Photo Library London

***Superconductivity** is the wave of the future. Conductors at temperatures nearing –273° C – absolute zero – have almost no resistance to electricity. This means that a magnet can be held suspended in a loop of super-cold wire.*

so great that it affected the picture quality on many television sets!

All domestic electricity supplies are carried from the nearest substation by at least two wires, usually underground. These wires enter a fusebox where a number of fuses protect the circuits and appliances inside the house. A fuse is simply a wire that overheats and melts if too much electricity passes through it.

'Ring' main

Several circuits branch out from the fusebox. One type powers the ceiling and wall lights. Another is the main 'ring' circuit that runs around the house, between the walls and under the floorboards. Each circuit consists of a live wire and a neutral wire – which are both connected to the substation – and an earth wire that conducts current harmlessly to the ground if an appliance fails.

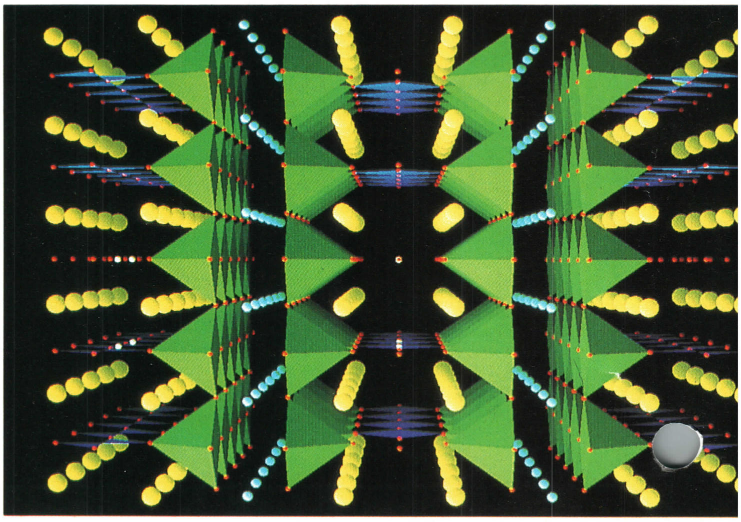
The amount of current entering the house is measured by a meter. This contains a small motor, connected to a counter, that runs faster as more electricity is consumed. The meter clocks up the amount of electricity used and the reading is then used to determine the amount of a household's electricity bill.

Even the best conductor offers some resistance to a current and so wastes energy. But if a substance is cooled down to a very low temperature, it loses its electrical resistance altogether. It is then said to be 'superconducting'. With no resistance to slow it down, a current could theoretically flow around a superconducting circuit forever.

Warm superconductors

Until recently, the highest temperature at which a substance was known to superconduct was –250°C; the conductor was a metallic niobium-germanium alloy. But in 1986, there was a major breakthrough. Scientists discovered a number of complex materials containing metallic substances such as thallium, lanthanum and yttrium that would superconduct at around -126°C, a temperature warm enough to be produced in a school laboratory.

These new materials offer the hope of practical applications for superconductors in the future. One such use might be in a national grid. Made from superconducting materials, power lines would not lose any energy during transmission. Another use of the new superconductors might be in building an extremely fast computer.



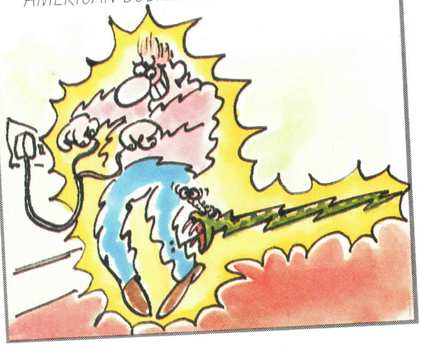
Chemical Design Ltd/SPL

***A new generation** of superconducting materials were discovered in 1987. This is a computer model of the molecular structure of one of them – yttrium-barium-copper oxide.*

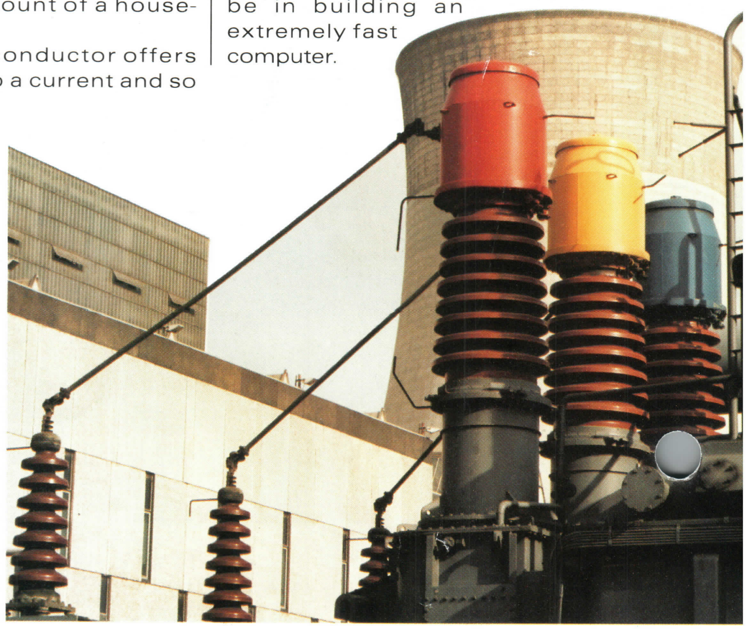
Just amazing!

SHOCKING CURE

A SERIES OF RAPID, 25,000-VOLT SHOCKS, IT HAS BEEN FOUND, IS AN EXCELLENT CURE FOR THE BITE OF DEADLY SNAKES SUCH AS THE SOUTH AMERICAN BUSHMASTER.



Paul Raymonde



National Power

***Power stations** transmit electricity at very high voltages, which is stepped down later for safe domestic use. High voltages cut transmission losses, but huge ceramic insulators have to be used to prevent shorting.*

Spectrum Colour Library

HI-TECH MINES | POWER STATIONS | POLLUTION

KING COAL

COAL SUPPLIES A HUGE SLICE of our energy needs, despite its reputation for being a dirty fuel and dangerous to extract. But the image of coal is changing. New technology is revolutionizing mines, while coal-burning is becoming cleaner and more efficient.

Most of the world's coal supplies started to form during the Carboniferous Period, from 360 to 280 million years ago. Decomposed plant matter in a moist environment, such as a swamp, broke down into peat. Buried underground, squeezed and heated, the peat gradually turned into coal, first into lignite, or brown coal, then (as the pressure and heat from above increased) into common bituminous coal, and finally into shiny black anthracite. A layer of peat around 5 metres thick will compress into a seam of coal some 30 cm deep.

As coal seams formed, the pressure forced out oxygen and hydrogen from the plant remains, leaving mainly carbon. Wood contains 50 per cent carbon, while lignite has 70 per cent and anthracite 94 per cent. It is the carbon that burns, helped by pockets of trapped oxygen and hydrogen gas.

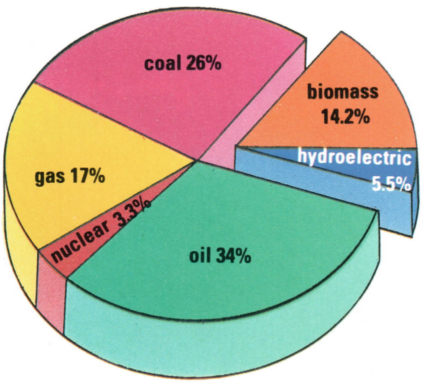
Coal is mined by two distinct methods: surface mining and underground operations. In surface mining – also known as opencast or strip mining – the layers above the coal seams (the overburden) are stripped away. The overburden can be more than 100 metres deep. The biggest surface mines produce just under 50,000 tonnes of coal a day.

The majority of the world's coal, however, is brought up from underground, from seams as deep as 1,200

***An opencast mine** in Germany. The sides of a surface mine are cut away to form a series of steps called benches. So the deeper the hole, the wider the area it must cover. Much coal, however, is mined underground. This coal face (right), in a mine in Kentucky, USA, is sliced with vertical strokes by a series of cutting edges mounted on a drum.*

Costain Group

World Consumption of Energy



Mark Franklin

***Coal, oil, gas and uranium** will all eventually become uneconomic to mine. The top two renewable sources are heat from burning organic matter (biomass) and hydroelectricity.*

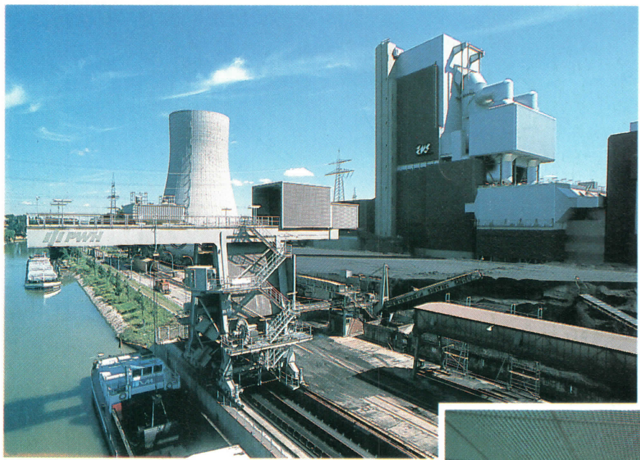
metres below the surface. Geological surveys provide data on which are the most promising seams and how they are laid out. In the most up-to-date mines, cutting machines are steered from a computer console in an underground operations room.

As the excavation proceeds, electronic guiders on the cutter transmit signals back to the console giving the machine's exact position. Sensors around the mine also warn the control-room of that most feared danger – a potentially explosive build-up of methane gas. Other sensors monitor the quality of coal being extracted and tell if equipment needs replacing.

Electricity

The great majority of coal that comes out of the ground is consumed in power stations for making electricity. About 50 per cent of the UK's electrical energy, for example, is supplied by burning coal.

At a power plant, the coal is first pulverized into fine pieces so that it will burn more efficiently. The burning itself takes place in a huge, box-shaped boiler. The inner walls of the boiler contain tubes in which water is converted into steam. The steam passes through a superheater, where its temperature and pressure are increased, before it drives a high-pressure turbine. A shaft from the turbine turns a generator that produces electrical current. A typical boiler consumes 500 tonnes of finely ground coal an hour – enough to generate a million kilowatt-hours of electricity.



Energie-Versorgung Schwaben AG

***Heilbronn power station,** run by operators manning computers in a central control room (below), is one of most modern coal-fired power stations in Germany, and one of the largest in the world to have a complete flue-gas cleaning programme.*

Energie-Versorgung Schwaben AG

Reducing pollution

Burning coal creates a number of problems, however. It contributes to the global 'greenhouse effect' by producing large amounts of carbon dioxide. It also gives off a number of poisonous substances, the worst of which is sulphur dioxide. When sulphur dioxide mixes with water droplets in the air, acid rain forms. This has killed millions of trees across Europe and North America.

To reduce their environmental impact, coal-fired power stations are being equipped with a variety of pollution-control systems. The most important of these is a flue-gas-desulphurization system called a scrubber. An alkaline substance, usually lime or limestone, is mixed with water and sprayed on to waste gas coming up the flue. The sulphur dioxide combines with this slurry to form calcium sulphate, or gypsum. In another process, in which crushed coal and limestone are suspended in a blast of air while they are burning, the limestone captures 90 per cent of the polluting gases given off.

***Gypsum** is a by-product of the coal burning process at Heilbronn, produced when limestone slurry combines with the sulphur in waste gas. Pressed into briquettes, it is sold as a building material.*

Energie-Versorgung Schwaben AG

BURIED IN PEAT

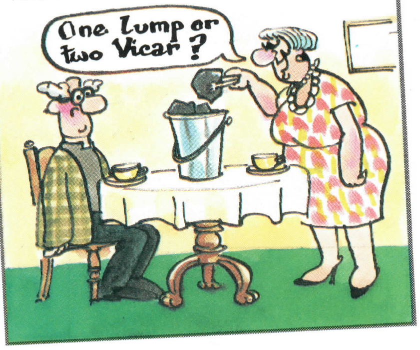
Trustees of the British Museum

As vegetable matter is compressed beneath the living surface of a bog it gradually turns into thick, black peat. Dried and cut into bricks, peat was once used to insulate cottages and it is still burned as fuel in many parts of the world. It is also an amazingly good preservative of animal and human remains. In 1985, for instance, the skin-covered head and upper torso of a man (above) was dug up from a peat-bog near Wilmslow in Cheshire, UK. Analysis showed that he had been garotted – strangled with a twisted cord – around 2,000 years ago.

Just amazing!

THAT COAL BLACK MAGIC ...

AMONG SOME OF THE MORE SURPRISING PRODUCTS MADE USING COAL ARE NYLON, SACCHARINE SWEETENER, MOTHBALLS, WEEDKILLER AND ANTISEPTICS.



Paul Raymonde

BLACK GOLD · GRAVITY SURVEYS · HOT PONDS

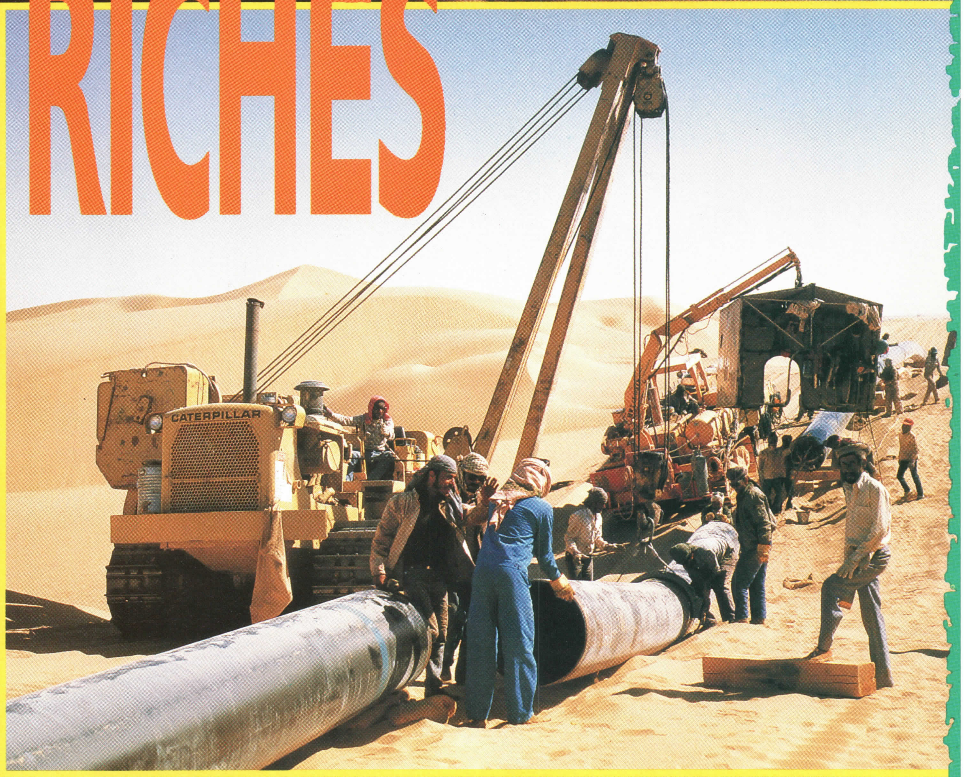
HIDDEN RICHES

SOME OF THE DESERT areas of the world contain very rich mineral deposits. And in the Middle East, in particular, there are huge underground reservoirs of oil – a vital commodity for the economy of the world.

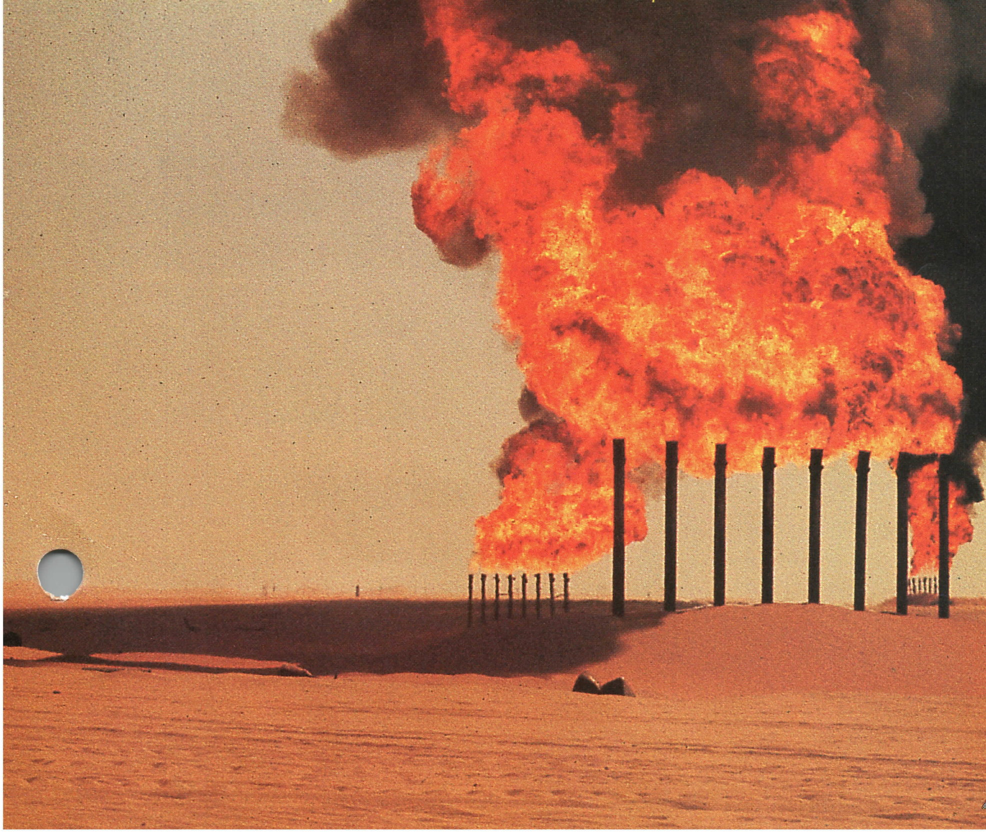
Four methods are used in finding sites to test drill for oil: surface feature mapping; seismographic observations; Earth gravity surveys and satellite sensing. The most obvious way is to look for signs on the surface such as tar sands or oil films on water in streams. A salt dome – bulging slightly in otherwise flat ground – is a good place to look as it is also a sign of an oil trap.

Satellite surveys

Remote sensing from satellites can speed up mapping and exploration. They show features that are invisible to the geologist in the field and cover vast areas. An important satellite for surveying is the Landsat Thematic Mapper. This takes pictures at wavelengths that are not normally visible. From these it is possible to tell apart common rock types and also detect potentially valuable formations. It shows up geological features, such as folds or faults. These features can ease the passage of fluids that concentrate metals and hydrocarbons.



Tony Stone Photo Library, London



R Bond/ZEFA

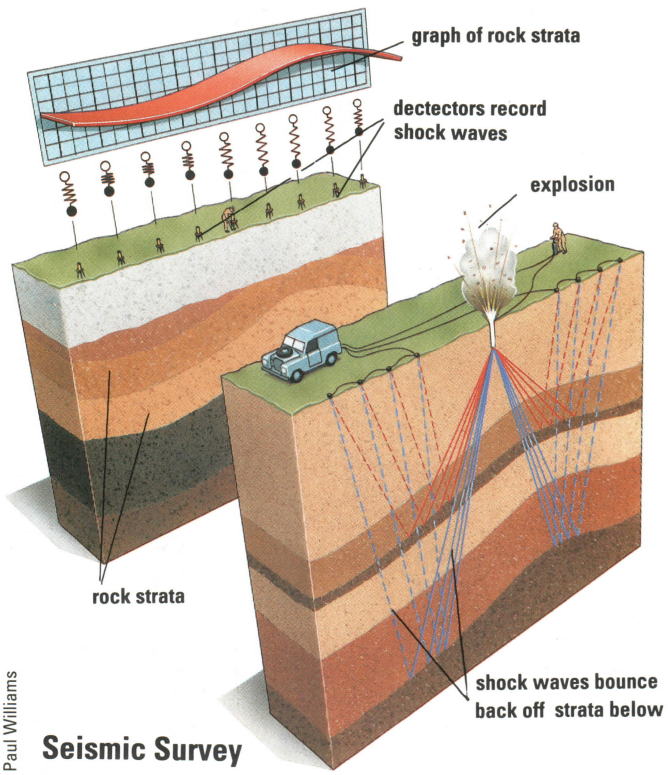
***Pipelines** (above) transport crude oil from wells to ports for shipping, or to refineries (below), which process petroleum into different oil products.*

But as most subsurface folds and faults do not show themselves on the surface, geologists have to detect them by other methods. The first of these is likely to be the gravity survey. Although the acceleration due to gravity at the Earth's surface is relatively constant, it changes fractionally where there are heavier or lighter rocks close to the surface.

Sound waves

Salt domes can be picked out because salt is lighter than many other rocks and the gravity survey – usually carried out from the air – picks up a lessening of the gravitational field. Gravity surveys can also spot fault blocks and anti-clinal folds, both likely spots for an oil accumulation.

When the gravity survey picks up some likely spots, the geologist moves in to do more detailed seismic surveys. Different rocks transmit sound waves at different speeds and where two types of rock meet, sound waves are reflected. So by sending a



Paul Williams

__To build up__ a graphic picture of the subsurface, geologists record the shock waves generated by explosions and analyse their speed with computers.

powerful vibration through rock, a picture of the features below can be built up, rather like a sonar or echo sounder at sea sees underwater features.

Finally, if the survey shows that there might be oil-bearing formations below, it is time to drill a test borehole. The familiar derrick with its rotating drill pipe tipped by the drill bit can bore as deep as 7,500 metres. Mud is pumped into the drill pipe hole to prevent unwanted fluids flowing into the hole and to carry rock samples and other fragments back to the surface.

If the reservoir is economically viable, a pipe slightly thinner than the borehole is sent down and cement is forced into the gap between the hole and this pipe. This seals the borehole from the oil so the casing has to be blown open by explosives, allowing the oil to enter the pipe. When the oil starts to flow or is pumped to the surface, the well is topped with a 'Christmas tree' valve to regulate the flow and allow apparatus to be lowered for repairs and assessment.

There are many other ores and minerals including gemstones extracted from desert or arid areas. These include the diamond mines of Namibia in southern Africa and those at Kimberley in Western Australia, estimated to contain one third of the world's natural diamond supplies; the town of Mount Isa in Australia where copper, lead, zinc and silver are mined; and the iron ore fields and mines at Zouerate in northern Mauritania in the Sahara.

There is plenty of sunshine in the deserts and there is also, usually, plenty of salt. These resources can be exploited separately and together. Sunlight can be converted into electrical current using semiconductor solar cells, focused by mirrors in a solar furnace and used to heat water or air in solar panels. It also has the power, combined with the dry air, to quickly evaporate water from a mineral-bearing mixture, leaving behind pure crystals. One example of this is the potash mine near Moab, Utah, USA.

Evaporation ponds

Water from the Colorado River is pumped down to the ore deposits over 900 metres below the surface. The ore dissolves in the water and the mix is brought back to the surface and stored in large, shallow evaporation ponds. After 12 months, pure potash crystals are left, for use in fertilizers, glass and soap.

One of most hellish mines on Earth was created by evaporation. In an area of north-eastern Ethiopia, called the Danakil Depression, the bed of Lake Assale is all that remains of a cut off and evaporated branch of the Red Sea. In temperatures regularly up to and over 50°C, miners lever huge slabs of salt from the lake bed, which are cut into bricks and taken by camel train to market.

__Mining for salt__ in the Niger. Rock salt can be found even in land-locked countries, where the mineral was deposited millions of years ago by seas that have now evaporated.

Dave Brinicombe/Hutchison Library

__An open-cast__ diamond mine in South Africa is being converted to deep mining. Although more expensive, underground mines are worthwhile for valuable minerals such as diamonds.

De Beers Consolidated Mines Ltd

Just amazing!

DOWN, DOWN, DOWN

THE BINGHAM CANYON COPPER MINE, UTAH, USA, IS SOME 800 METRES DEEP - THAT'S NEARLY TWICE THE HEIGHT OF THE WORLD'S TALLEST BUILDING.

Paul Raymonde

Interim Index (1)

This index is in alphabetical order. The six subject areas are keyed as follows: SF – SPACE FRONTIERS, NT – NEW TECHNOLOGY, F – FUTURES, PE – PLANET EARTH, ER – ENERGY AND RESOURCES, LW – LIVING WORLD. Complete articles are marked **bold**. So LW **77–80** is LIVING WORLD pages 77–80. File your index at the back of your binder for easy reference.